Return to the Exit Ticket

Turn and Talk

- How did you think speed would affect the distance and time it takes to stop after the driver hits the brakes?
- What other factors might affect how long it takes to stop after the driver hits the brakes?

→ Be ready to share your ideas with the class.

Slide B

Consider What Makes Good Brakes

When you press the brakes, a **friction force** is applied to the car that engineers call the **braking force.**

Turn and Talk

- In which direction is the braking force on the car in the image? How do you know?
- If a driver "brakes harder" than another driver, what is different about the braking force?

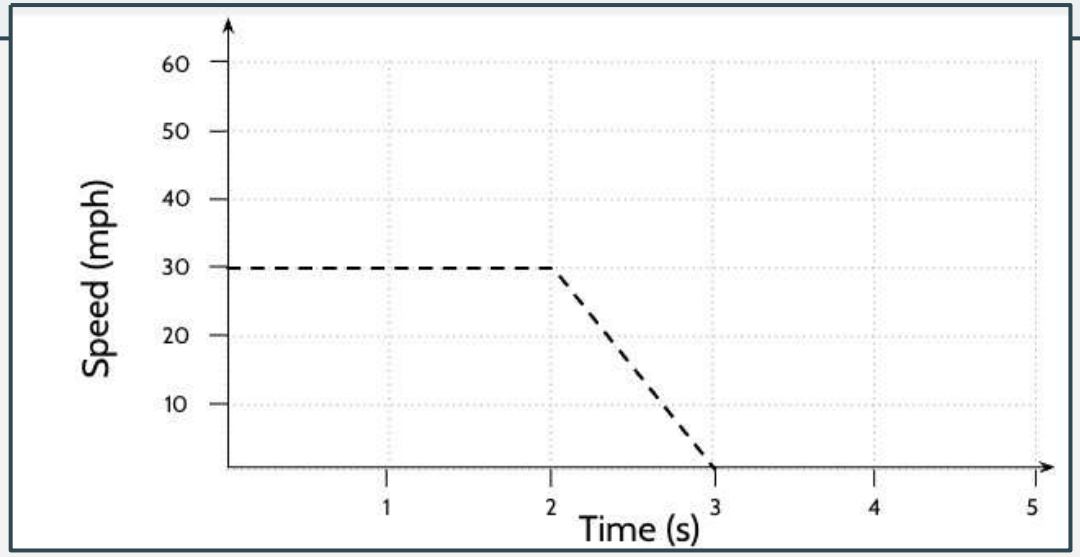
→ Be ready to share your ideas with the class.

Speed versus Time Graph

On your own

How will this graph change if the car:

- is moving faster?
- experiences more braking force?
- has more mass?



Interpret a Speed versus Time Graph

With a partner

- Identify any specific points or regions on the graph where the speed:
  - remains constant
  - changes
  - reaches zero
- How would you represent in the graph a car that is traveling at the same speed and:
  - takes less time to stop?
  - takes more time to stop?

➔ Be ready to share your ideas with the class.

Make Predictions about Relationships

On your own

On your handout, make predictions about how the speed versus time graph will change if the braking force, initial speed, or mass is doubled/halved.

➔ Be ready to share your ideas with the class.

Slide F

Orient to Investigation Materials

With your class

Orient to the materials for the investigation.

- What is our **dependent** variable?
- What are our **independent** variables?
  - How can we change each independent variable?
  - How do we keep the other variables constant?
- How do we measure these variables?

Slide G

Safety Protocols

With your class

- Read the safety protocols on the lab handouts, follow the activity instructions, and only conduct the assigned activities.
- Dress appropriately: closed-toe shoes, long hair and loose clothing tied back, and safety glasses.
- Keep workspace and floor clear and check equipment for damage.
- Stay a safe distance from the collision area.

Practice Data Collection

With your group

- Read the directions on your group's *Data Protocol* reference.
- Follow the directions to collect practice data for 1 condition.
- Record your initial data on your *Braking Investigation* handout.

Discuss Practice Data

With your class

- How did the your group's results compare between trials?
- What factors could explain the difference in these results?
- What could we do to improve the accuracy of our results?
- What are the advantages and disadvantages of collecting data with this setup?

Discuss Practice Data

With your class

While collecting data, what are some steps we can follow to increase the accuracy of our results?

Collect Data

With your group

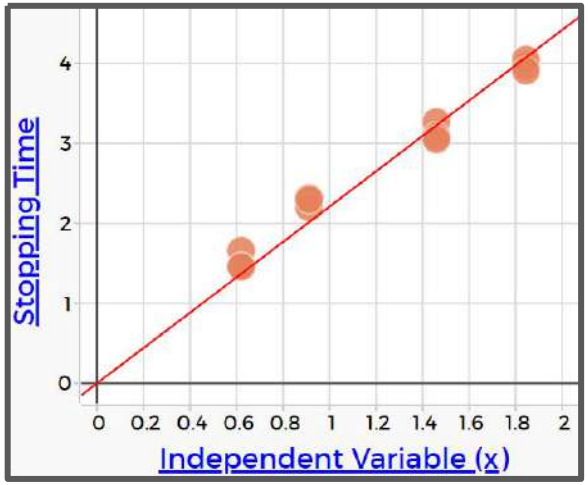
- Follow the directions to collect data for your independent variable on your *Data Protocols* reference.
- Record your data in the Data Collection section of your *Braking Investigation* handout and enter it into CODAP.
- Complete the Data Analysis section of your *Braking Investigation* handout.

Analyze Data

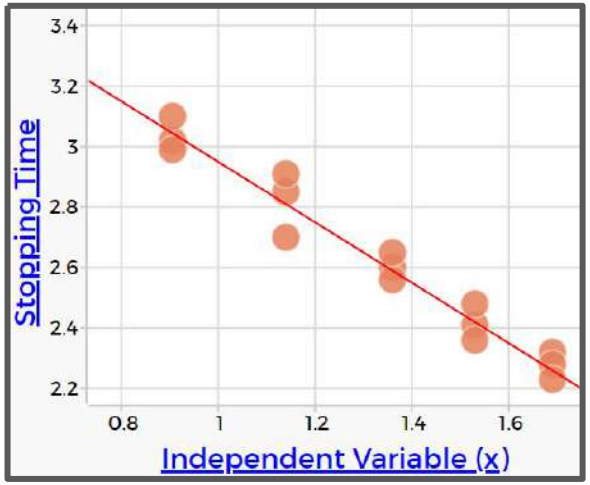
With your class

Based on your results, how would you say the variable you investigated is related to time?

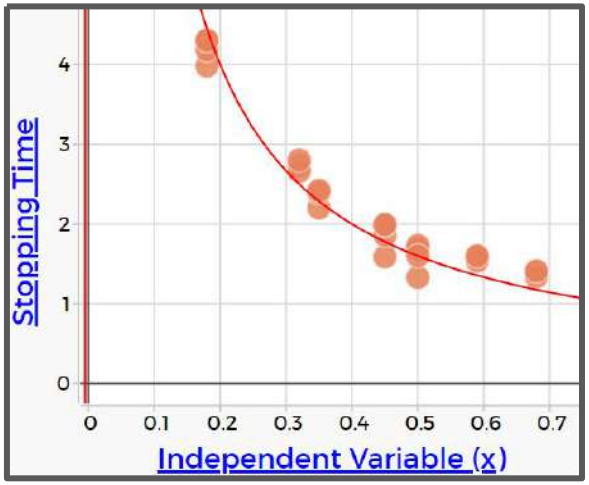
Linear (+)
time = a * x



Linear (-)
time = (-b * x) + c



Inverse
time = d/x



Images generated using CODAP (https://codap.concord.org/), developed at the Concord Consortium

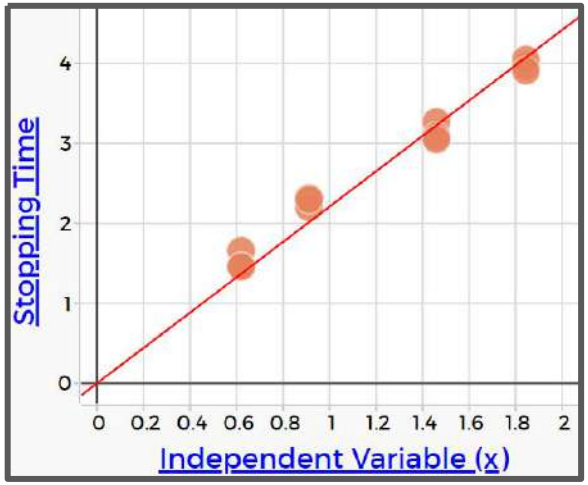
Analyze Data

With a partner

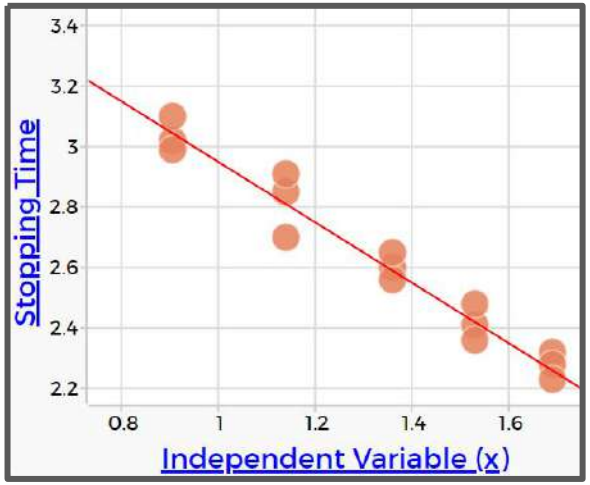
Answer the Discussion Questions on your lab handout.

➔ Be ready to share your predictions with the class.

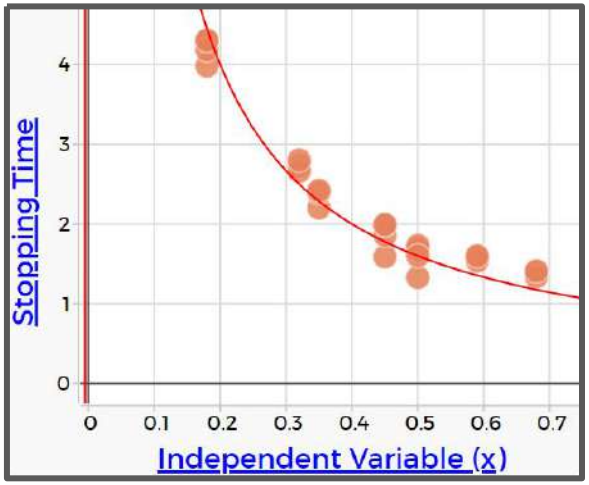
Linear (+)
time = a * x



Linear (-)
time = (-b * x) + c



Inverse
time = d/x



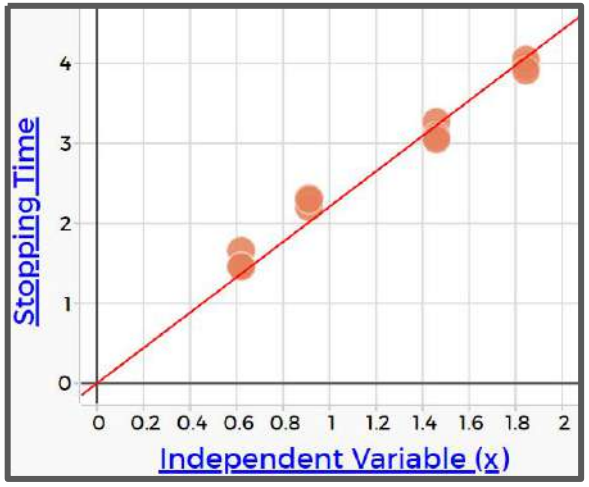
Images generated using CODAP (https://codap.concord.org/), developed at the Concord Consortium

Analyze Data

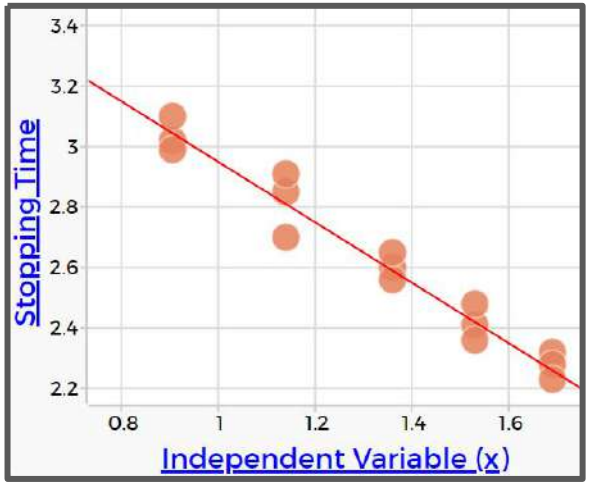
With your class

What would happen to the stopping time if we **doubled** the independent variable you investigated?

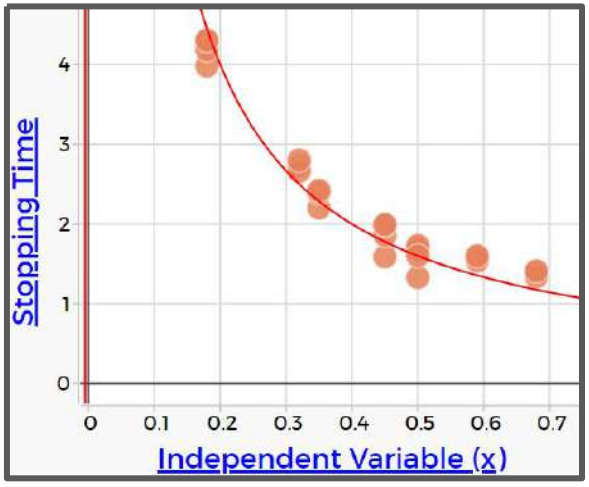
Linear (+)
time = a * x



Linear (-)
time = (-b * x) + c



Inverse
time = d/x



Images generated using CODAP (https://codap.concord.org/), developed at the Concord Consortium

Navigate: Consider Vehicle Safety

With your class

Does increasing the independent variable you investigated make things safer or riskier for people? Why?

Predict Effects on Stopping Time

With your class

- Work through 2 predictions in which you double 2 of the variables.
- What did you do with the numbers to make these predictions?

Predict Effects on Stopping Time

With your class

What would happen if all 3 variables changed?

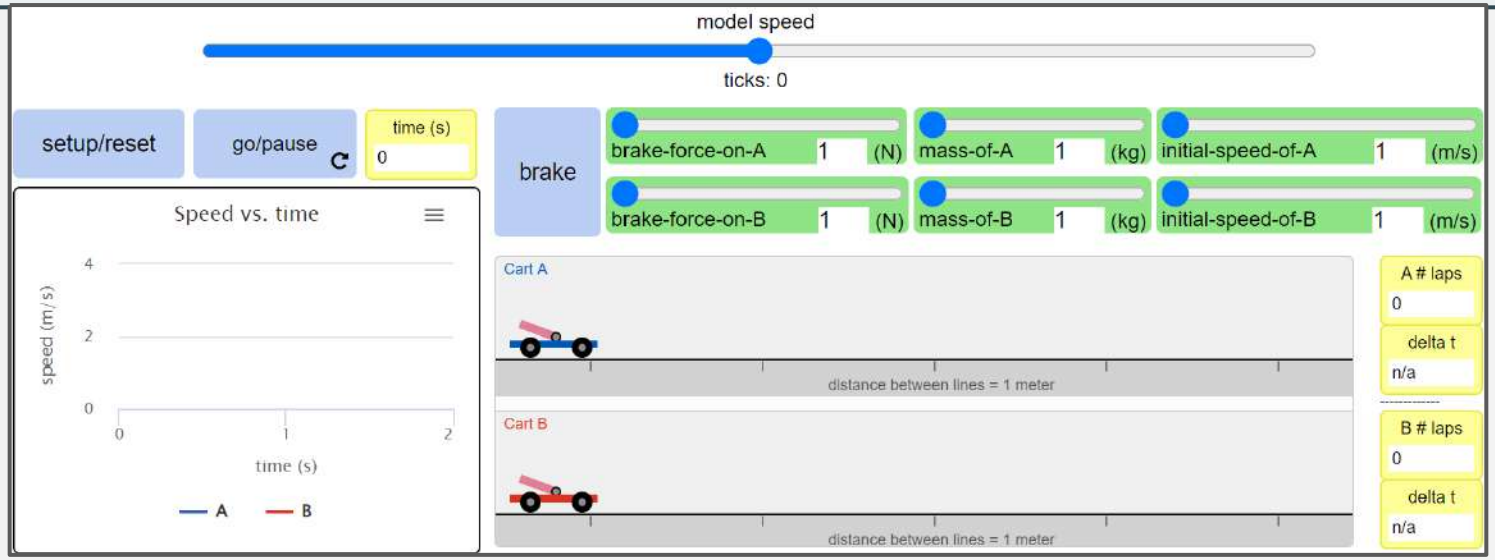
- 4 times the mass, 3 times the speed, 2 times the braking force
- 8 times the mass, 3 times the speed, 6 times the braking force

What data would make you more confident about our answers?

Use a Simulation to Gather Additional Data

With your group

- Set up a data table to record mass, speed, and force combinations for at least 3 conditions.
- Use this link: https://www.openscied.org/simulation/braking/



Wilensky, U. 1999. NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University. Evanston, IL.

Make Sense of Results

With your class

- How is the data collected in the simulation different from the data collected using the physical carts?
- What are the advantages and disadvantages of collecting data with the simulation?

Make Sense of Results

With your class

- What relationship have you discovered between mass, speed, and braking force that predicts the stopping time of a vehicle?
- How can we represent the relationship we have identified as an equation?

Use Our Models

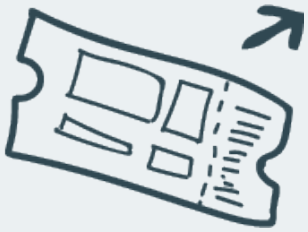
On your own

$$\Delta t = \frac{m * \Delta \text{ in speed}}{F}$$

In the following examples, use our mathematical model to predict the stopping time (Scenario A) and braking force (Scenario B):

- **Scenario A:** A car of 3,000 kg is traveling at 20 m/s and the driver applies a braking force of 15,000 N.
- **Scenario B:** A car of 2,500 kg is traveling at 30 m/s and the driver needs to stop in 1 second. What is the minimum braking force needed to do this?

Navigate



Exit Ticket

- On your handout, make predictions about how the speed versus time graph will change if the braking force is tripled.
- Explain your reasoning using the mathematical model we developed.

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